A Practical Guide to Dose Optimization in the Interventional Radiology Arena

North Carolina Health Physics Society
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Before we continue...

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One personal disclosure
“ALARA” attack profile
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Goals and Objectives

1. Discuss practical techniques which optimize the patient dose during fluoroscopically- and CT-guided procedures.

2. Understand techniques which provide operator protection in the angiography suite.

3. Discuss the question, “Do I really need all that image quality?”
Why examine this?

1. Increasingly more complex equipment

2. Interventionalists spend little time learning how to balance image quality and dose

3. Operator often focused on clinical problem at hand (embolization, stent placement etc), not on balancing image quality and patient dose
Medicine ⇔ Airline Industry
Washington’s Reagan National Airport Control Tower Goes Silent

Chicago plane finds snoozing tower in D.C.
Pre-Flight Check List
I SAVE DOSE
Increase table height (table Up, top Down)
Increase the Table Height

Why?
Source to Skin Distance

- SSD: determined by table height and the operator’s height
- Skin dose decreases as SSD increases
- Therefore, maximize SSD within reason
  - 700 mm (27.6 inches)
  - 600 mm (23.6 inches): increase dose 17-29%
  - Simple 10 cm (4 inch) maneuver

Wagner LK, Archer BR Cohen Am.JVIR 2000;11:25-33
600 mm
23.6 inches
700 mm
27.6 inches
17-29% dose decrease
Source to Skin Distance

- Think about the lateral as well!
EP with biplane fluoro
Minimize the Air Gap

Skin dose decreases as air gap decreases

10 cm air gap = 20-38% increase in skin dose

Wagner LK, Archer BR Cohen Am.JVIR 2000;11:25-33
Good Technique
Minimize Air Gap
Maximize the SSD
Poor Technique
10 cm Air Gap
20 – 38% increase in dose
+
Diminished SSD
“Table Up, Top Down”

Increase Table Height
Increase table height (table Up, top Down)
Slow the Frame Rate
Slow the Frame Rate

- Fluoroscopic Frame Rate
- DSA acquisition Frame Rate
Pulsed Fluoroscopy

15 – 30 pps for critical procedures where precision required

7.5 pps used for many cases
  Up to 70% dose savings compared with continuous fluoro *

3 pulses per second
  Used when dose savings are paramount or for simple procedures

75 yo male ESRD

Left Arm Fistula
15 Frames/second
3 Frames/second
Following Angioplasty
I Save Dose

I  Increase table height (table Up, top Down)
S  Slow the Frame Rate
A  Add Barriers
V  E  D  O  S  E
Add Barriers

- Your Lead
- Staff’s Lead
- Leaded Glasses
- Lead Drape on Table
- Leaded Ceiling Mounted Shield
- Standing Shield
Hepatic Embolization
Hepatic Embolization
Hepatic Embolization
Protecting the Operator

- Scatter is greatest contributor to operator dose
- Greatest on entrance side
- Limiting patient dose = limiting operator dose usually
  - Dose spreading
  - Increasing SSD
Primary Beam

Mark S. Rzeszotarski, PhD
Typical Interventional Suite
Siemens Uroskop
Ceiling Mounted Shields
Rolling Shields
Disposable Protective Drapes

- Reduced scatter by:
  - 12 fold for the eyes
  - 25 fold for the thyroid
  - 29 fold for the hands

King et al. AJR 2002;178:153-157
Weightless Apron
Weightless Apron

- Zero Gravity System
  Added head protection
  Left arm sleeve

Savage et al. SIR abstract 2009
I Save Dose

Increase table height (table Up, top Down)
Slow the Frame Rate
Add Barriers
Vary the Technique
Vary the Technique

- Vary the angle
- Vary the Collimation
  - Tight collimation
    - Improves image quality
    - Reduces Patient Dose
    - Reduces Operator Dose
- Vary the acquisition rates
Surface between arrows received dose in both gantry positions.

Tighter collimation will limit the degree of overlap.

Dose Spreading

UAE
Peak Skin Dose
1374 mGy

UAE Dose Spreading
Collimation
PSD = 939 mGy

I Save Dose

Increase table height (table Up, top Down)
Slow the Frame Rate
Add Barriers
Vary the Technique
Exit the Room for DSA

DOSE
Exit the Room for DSA

- Leave the room for DSA runs
- Huge dose that you don’t have to be exposed to
I Save Dose

Increase table height (table Up, top Down)
Slow the Frame Rate
Add Barriers
Vary the Technique
Exit the Room for DSA
De-Mag
Dose
Magnification

- Dose Increase = \(\left(\frac{\text{Diam}}{\text{Diam}}\right)^2\)
- FOV From 28 to 14 = \(\left(\frac{28}{14}\right)^2 = 4\)
- Actual dose may be less
Uterine Artery Embolization
PA, non-magnified view
Black Arrow: Internal Iliac Artery
Uterine Artery Embolization
Magnified, oblique view
Black Arrow: Posterior Division
White Arrow: Anterior Division
Arrowhead: Uterine Artery
I Save Dose

Increase table height (table Up, top Down)
Slow the Frame Rate
Add Barriers
Vary the Technique
Exit the Room for DSA
De-Mag
Optimize
Optimize

- Review prior imaging:
  - CT, US, MRI
  - Prior Interventions
- Ask: “Do I really need all that image quality to accomplish the task at hand?”
I Save Dose

Increase table height (table Up, top Down)
Slow the Frame Rate
Add Barriers
Vary the Technique
Exit the Room for DSA
De-Mag
Optimize
Save Images
E
Save Images

• Save fluoroscopy images
  Last image hold
  For simple documentation

• Save fluoroscopy video clips
  May eliminate need for DSA
  May allow planning of best obliquity for DSA
Last Image Hold

Last Image Hold Spot Radiograph
How far can you push LIH?
I Save Dose

Increase table height (table Up, top Down)
Slow the Frame Rate
Add Barriers
Vary the Technique
Exit the Room for DSA
De-Mag
Optimize
Save Images
Eyes: Protect Them
Cataracts
Eye Protection

Typical workloads: dose to eye may exceed the threshold for cataracts after several years of work if radiation protection tools not used.

Vano et al. Radiology 2008;248:945-953
Protection from Head Scatter

1. Large lenses better than small

2. Scatter:
   a. Leaded face mask
   b. Freely supported, properly positioned leaded barrier
   c. Disposable protective drapes

Eye Protection

PANORAMA SHIELD
Operator Eye Protection

Thornton, Dauer et al. JVIR 2010
Comparing Strategies

• **Leaded Glasses:**
  reduced by a factor of 5 - 10

• **Scatter Shielding Drapes:**
  reduced by a factor of 5 - 25

• **Both Together:**
  reduced by a factor of >25

• **Suspended Shielded:**
  Undetectable

Protection from Head Scatter

1. Large lenses better than small

2. Scatter:
   a. Leaded face mask
   b. Freely supported, properly positioned leaded barrier

Metrics

- Physicians must be familiar with the equipment

- Metrics:
  - Do not use Fluoro Time if you have Reference Dose
  - Kerma Area Product

Machines without these metrics should not be used for complex procedures
Pre-Flight Check List

- Remember **I SAVE DOSE:**
  - Increase table height (table Up, top Down)
  - Slow frame rates
  - Add Lead
  - Vary technique: collimation, angle
  - Exit the room for DSA
  - De-mag
  - Optimize: Ask: how much image quality do I need?
  - Save Images: LIH and Fluoro video clips
  - Eyes: protect them
CT Studies by Year

Annual Growth > 10%/yr
U.S. Population < 1%/yr

Mettler et al. Health Physics 2008
CT Use

• 15% of radiologic examinations
• > 50% of total dose
# Benchmark Effective Doses

<table>
<thead>
<tr>
<th>Exam</th>
<th>Dose in mSv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Background Radiation</td>
<td>3.6 mSv</td>
</tr>
<tr>
<td>PA and Lateral CXR</td>
<td>0.1 mSv</td>
</tr>
<tr>
<td>CT of the Abdomen and Pelvis</td>
<td>8-11 mSv</td>
</tr>
<tr>
<td>CT of the Chest</td>
<td>5-7 mSv</td>
</tr>
</tbody>
</table>
CT-Guided Abdominal Procedures

Effective Dose by Procedure: before applying dose reduction protocol

Mean Effective Dose = 18.6 mSv
Pilot Dose Reduction Protocol

- Review the case with the technologist involved
- Limit the cranio-caudal length of initial localizing scan
- Reducing the mAs during the initial localizing scan
- Reducing the mAs during the procedure itself
- Default <50 mAs
Abscess Following Pelvic Exenteration

342 mAs
Initial Localizing Scan

mAs 75
Drain Placement
Results

• Mean Effective Dose: 5.2 mSv (2.1 - 14.6)
Comparison of Mean Effective Dose

CT-Guided Abdominal Procedures

Mean Reduction of Effective Dose = 29% of baseline
Comparison of Mean Effective Dose

CT-Guided Chest Procedures

Mean Reduction of Effective Dose = 38% of baseline
Clinical Implications

• Able to perform many procedures with mAs < 30!
### Refined Protocol

<table>
<thead>
<tr>
<th></th>
<th>&lt;150 lbs</th>
<th>150-285 lbs</th>
<th>&gt; 285 lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Scan</td>
<td>30 Ref mAs</td>
<td>70 Ref mAs</td>
<td>100 Ref mAs</td>
</tr>
<tr>
<td>Biopsy Mode</td>
<td>17 mAs</td>
<td>30 mAs</td>
<td>50 mAs</td>
</tr>
<tr>
<td>Spiral Scan</td>
<td>22 mAs</td>
<td>30 mAs</td>
<td>50 mAs</td>
</tr>
<tr>
<td>Post Scan</td>
<td>30 mAs</td>
<td>30 mAs</td>
<td>50 mAs</td>
</tr>
</tbody>
</table>
Do I really need all that image quality?

• No
• Adjust the dose to the task at hand
• Spread the word, train young physicians